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THE NEED FOR WEATHER SATELLITE OBSERVATIONS AND JAPAN'S WEATHER SATELLITES

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JAPAN

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THE NEED FOR WEATHER SATELLITE OBSERVATIONS AND JAPAN'S WEATHER SATELLITES (OUTLINE)

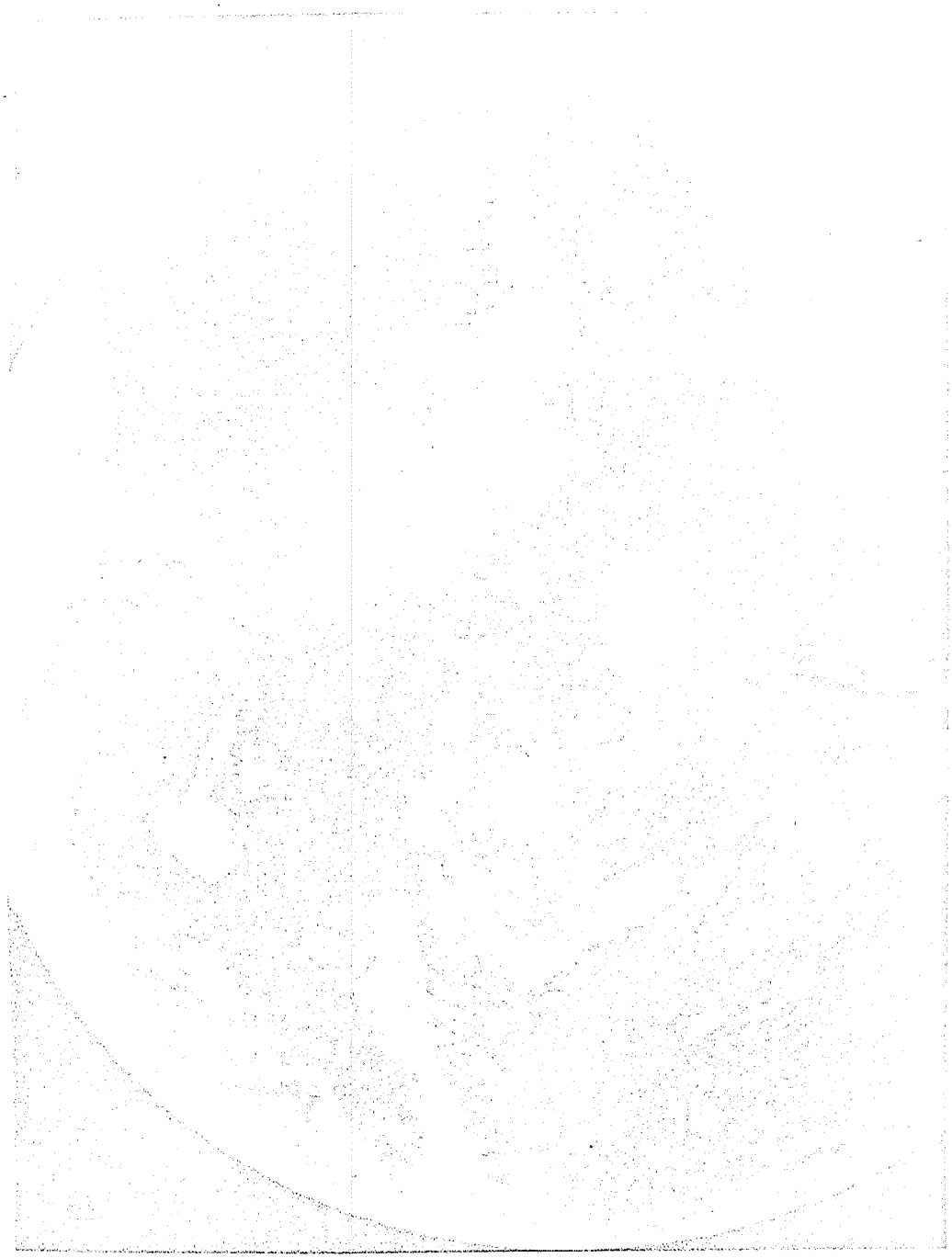
ABSTRACT. Weather satellite organizations and plans, and the construction of a satellite by Japan are discussed, and possible advantages and economic savings are listed.

I. The Global Weather Satellite Organization and the Role of Japan's Weather Satellites. /1*

1. The Functions of Weather Satellites.

Type of Weather Satellite	Observation Subject	Notes
Polar Orbit Satellites	The vertical distribution of air temperature and water vapor; horizontal distribution of clouds; temperature distribution on the surface of the land and the sea and at the top of the clouds.	Observation limits are generally 3,500 km square. The frequency of observations generally depends on the number of satellites, however, one satellite can make two observations daily.
Synchronous Satellites	Constant observation of typhoons, lows, fronts, and heavy rain and snow regions by cloud distribution and temperature measurements. Observation of stratospheric winds The collection and distribution of weather data from ships and automatic observation stations on land and at sea and the supply of warning reports to users.	Observation range is generally about 1/4 of the globe. Frequency of observation is about once every 20 minutes. Collection and distribution of data is more than four times daily.
Intersecting Inclined Orbit Satellites	Observation of wind distributions in the necessary atmospheric layers.	

*Numbers in the margin indicate pagination in the foreign text.



A nephogram taken by ATS-III (1650 Z GMT, 6 June 1968). ATS-III is stationary over the mouth of the Amazon River, South America, and the clouds appear white.

South America is in the center. The white band at the top is a front. The white eddy at the left end of the front is a hurricane.

2. Global Weather Satellite Organization.

(1) The World Wide Weather Observation Plan (WWW Plan) -- (Plan of the World Meteorological Organization (WMO)). These have the objective of improving weather service by greatly improved observations of conditions in the terrestrial atmosphere.

(2) The Global Atmosphere Development Plan (GARP) -- (A combined plan of the International Council of Scientific Unions (ICSU) and the MWO).

The objective is to increase the accuracy of forecasts made several /2
weeks in advance by increasing knowledge of the major circulation patterns of the atmosphere. The first global tests are planned for 1975-76.

COMPARISON OF THE WEATHER SATELLITE OBSERVATION ORGANIZATIONS IN WWW AND GARP

	Synchronous Weather Satellites	Polar Orbit Satellites	Intersecting Inclined Orbit Satellites	Objective Year	Notes
WWW	4* (Weather communication mission also considered).	3 - 4	2	To be established in stages.	Operational observations
GARP	4*	2 (Five nation launch plan)	2	1975	Research observations

*150° W, 70° W: Launched by the U.S.A. (1972, 1973).

20° E: Launched by France (1974).

120° E: Strong request for Japan to launch.

(3) Weather Satellites Supported by Japan.

Synchronous weather satellite over the equator at 120°E: constant observation of typhoons, lows, fronts and heavy rain and snowfall regions that will affect Japan.

II. Synchronous Weather Satellite Plan.

1. The Essentials of Synchronous Weather Satellite Systems.

(1) Weather observation subsystem: Window region infrared radiometer, visible light camera.

(2) Weather data collection and distribution subsystem.

(a) Relay weather data from ships and automatic observation stations on land and at sea.

(b) Transmission of forecasts, warnings, analytical data, weather maps, etc., to ships or other users.

(3) Weight: about 300 kg.

(4) CDA stations and data processing centers to control weather satellites and to acquire data are required.

(5) Satellites and subsystems to transmit and receive data are required. /3

(6) Launch target: end of 1975.

III. Anticipated Results, Cost Comparison and Future Development.

1. Anticipated Results.

Weather data necessary for weather analysis will become plentiful, increasing the accuracy of weather forecasts and warnings.

Example (1) Movements of typhoons will be known every 20 minutes reducing losses in life and property (natural disaster losses in Japan total several hundred billion yen annually).

(2) Numeric reports several weeks in advance will be possible.

(3) Data from unmanned domestic observation stations (rainfall, coastal disaster prevention observations) can be acquired, improving weather reporting service.

(4) Economic Evaluation. For example, as a result of accurate weather forecasting, annual losses to the American construction industries of more than 270 billion yen have been prevented.

2. Cost Comparison of Methods Dependent on Conventional Techniques and Facilities and those Dependent on Weather Satellites.

Excepting development costs, when the lifetime of weather satellites reaches 3 to 5 years, annual operating expenses will probably be 1.4 to 2.3 billion yen (including launching).

In contrast:

(1) Only within those ocean regions within which Japan bears the responsibility for weather service, ship construction costs would be 40 billion yen for the deployment of ocean-going, fixed position observation ships; annual operating expenses would be 12 billion yen and a large number of crew members and observation personnel would be required.

(2) The cost of aircraft to observe typhoons in the south seas would be 11 billion yen for facilities including aircraft procurement. Annual operating costs are about 4.5 billion yen and a large number of pilots and observation personnel would be required.

3. Future Development of Weather Satellites. /4

The following functions can probably be realized within the near future.

(1) Observation of rainfall regions and global measurements of precipitation.

(2) Observation of ocean conditions (waves, sea ice, ocean currents, etc.).

(3) Measurement of ozone, carbon dioxide gas and other atmospheric elements and observation of atmospheric pollution conditions.

Appendix: The Need for Independent Development in Japan. /5

1. Why do Australia and Other Foreign Countries Not Bear a Portion of the Cost of Satellites?

(i) The utility of synchronous weather satellites is almost entirely domestic.

(ii) Satellite No. 1 is an experimental satellite.

2. Should all Launchings be Ordered from America?

(i) Domestic elements constitute the principal portion of the usable coverage of synchronous satellites. In most instances, the weather is controlled by the geographic features distributed within a given country. The requirements placed on a satellite must take these points into consideration.

(ii) It is therefore optimal that the determination of missions for synchronous weather satellites be determined by the using country. It is not possible to resolve the difficulties caused by liaison, language and geographic factors in mission determination. Such an arrangement would ultimately cost more than autonomous development.

(iii) If various types of satellites are used in the future, there will be many features common to all such satellites that can be exploited, reducing initial research and development costs. There will be far-reaching benefits to development techniques as well.

3. The Burden of Future Costs.

The benefits to each country, the economic ability to bear the costs, etc., will probably be studied through the WMO.

THE NEED FOR WEATHER SATELLITE OBSERVATIONS AND JAPAN'S WEATHER SATELLITES

I. World Weather Satellite Organization and the Role of Japan's Weather Satellites.

1. The Functions of Weather Satellites.

The weather satellite is one of the technological developments which should be most acclaimed for effectively providing weather observation in unpopulated regions that have been impossible to cover in the past with conventional methods (oceans, deserts, polar regions, etc., which occupy some 70% of the surface of the globe). The development of further new observation methods may also be anticipated in the future.

The functions of the weather satellites that have been developed up to the present time are as follows:

(1) Weather Satellites in Polar Orbit.

Measurement of the vertical distribution of terrestrial atmospheric temperature and water vapor, the horizontal distribution of clouds and the temperature distribution on land surfaces, ocean surfaces and the tops of clouds in the areas below the orbit.

(2) Weather Satellites that Remain Stationary over the Equator.

(i) Constant observations of atmospheric disturbances, such as typhoons, lows, fronts, heavy rain and snow regions, etc., between 60° north and south latitudes and about 120° east and west. (See page 2, a photograph of cloud distribution).

(ii) Observation of stratospheric winds from cloud movement measurements.

(iii) The acquisition of weather data from ships and automatic observation stations located at a distance on land and at sea.

(iv) The supply of such processing data as raw data, forecasts, warnings, analytical data, weather maps, etc., to users.

(3) Weather Satellites in Inclined, Intersecting Orbits.

Observation of the requisite wind distribution in each of the atmospheric layers when combined with suitable pressurized, fixed altitude balloons.

2. World Weather Satellite Organization. /8

(1) The World-Wide Weather Watch (WWW) Plan.

World-wide deployment of weather satellites is necessary to effectively exploit the functions of weather satellites. The World Meteorological Organization (WMO) is promoting the development of a world weather satellite organization (as part of the WWW Plan). The WWW Plan is a plan for improving weather service through greatly improved observation of the state of the terrestrial atmosphere by utilizing the newest techniques. This plan contemplates the full participation of weather satellites in weather observation and the collection and distribution of weather data. The weather satellite organization currently under consideration in the WWW Plan is as follows.[1]

(i) Four synchronous satellites. Constant observation of atmospheric disturbances and the collection and distribution of weather data.

(ii) Three or four polar orbit satellites. Measurement of the vertical distribution of atmospheric temperature and water vapor up to cloud layer altitudes, the horizontal distribution of clouds and the temperature distribution in the clouds and on the surface of the earth six to eight times daily.

(iii) Two intersecting inclined orbit satellites. Measurement of winds in each atmospheric layer in combination with pressurized, fixed altitude balloons floating in the atmosphere.

(2) The Global Atmosphere Development Plan (GARP - Global Atmosphere Research Program).

There are a number of requirements that must be met to achieve the improvement of weather service through the WWW Plan covered in (1) above.

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1. The WMO WWW Satellite Subcommittee conversations (Geneva).

The most important of these is the determination of observation methods for a numeric forecasting model in order to produce more accurate forecasts several weeks in advance. The WMO is promoting the GARP plan in concert with the Inter- /9
nation Council of Scientific Unions (ICSU) as one of the research plans that will form a pillar of the WWW Plan to solve this problem.

The GARP is a plan for universal cooperative research to achieve a great leap forward in our knowledge of major atmospheric circulation patterns, thereby increasing the accuracy of forecasts prepared several weeks in advance and, if possible, attaining the final objective of regulating the world climate. It is directed at the resolution of the above problems. The large-scale, first GARP global experiment (FGGE), in which the entire world will cooperate, has been planned for 1975-76. Practical plans have been studied in various meetings subsequent to 1967, however the FGGE is an important element in the experimental stage of weather satellite development. The plan contemplates the efficient conduct of experiments in which weather satellites will be freely used for weather observation and the collection of weather data.

The deployment of weather satellites for this purpose was decided as follows in the GARP planning conference held in March, 1970, in Brussels. (See Appendix Figure 1). The decision conforms to the aforementioned WWW Plan. It calls for four synchronous satellites equipped for the dual functions of weather observation and the collection of weather data, two polar orbit satellites, that will perform weather observations principally through infrared radiometry, and two intersecting inclined orbit satellites combined with pressurized, fixed altitude balloons to measure winds.

The orbiting satellites will incorporate the requirements of several countries. These are at the stage in which coordination among the interested countries now is necessary. The synchronous satellites will be as follows:

150°W. United States to launch (designation: SMS) last half of 1972.

70°W. United States to launch (designation: GOES) around mid-1973.

20°E. France to launch in 1974.

120°E. Strong request being made for Japan to launch.

(3) Weather Satellites Supported by Japan.

As stated before, the number of weather satellites in the global satellite organization will total some eight or nine under the WWW Plan. From the viewpoint of the benefits to Japan, her economic strength and technological capabilities and for the reasons given below, that Japan maintain and operate a synchronous satellite above the equator south of Japan would be the optimum choice. This would be of benefit to Japan, but also probably would be responsive to global requirements. /10

It is intended that further studies be made on the development of orbiting weather satellites.

(1) A synchronous satellite at 120°E would make constant weather observations possible over an extensive area between 60° north and south and from the western Pacific to the Indian Ocean. Accordingly, constant surveillance over such weather disturbances that affect Japan as typhoons, lows, fronts and regions of heavy rain and snow would be possible. Such a satellite would permit increased accuracy in weather forecasts, but would also perform the service of providing an effect point for relaying weather messages (Appendix Figure 2).

(2) In the WWW Plan, Japan has promised to accept the mission for a regional meteorological center (RMC) and an air region forecast center (AFC) for the Far East. In order to meet this responsibility, it will be necessary to collect observation data for the ocean and air regions for which responsibility exists and to distribute analytical data from the RMC and the AFC within the same region. A synchronous satellite over the equator south of Japan would be the most effective instrument for this purpose as well. It may be anticipated that Japan's service to this marine and air region would be further improved as a result.

(3) In both the WWW Plan and GARP, there are strong requests for Japan to launch the 120°E synchronous satellite that will be one of the four synchronous satellites that are to form the framework of a global observation network.

(4) There is no other country in the Asian region that can launch such a satellite. If Japan does not do so, there will be a large void in weather observations throughout the entire region from the Indian Ocean to the West Pacific.

(5) Among the various types of weather satellites described in Paragraph 1, both the United States and the Soviet Union currently have operating orbital satellites. A number of other countries have published plans to launch such satellites and the stage has been entered at which coordination between the interested countries is now required. /11

II. Synchronous Weather Satellite Plans.

1. The Essentials of Synchronous Weather Satellite Systems.

As shown in Figure 1, which shows the synchronous weather satellites currently under consideration, one will be stationary over the equator at 120°E. A weather data collection and distribution subsystem is woven into the weather observation subsystem, which has the following missions. The observation limits of this synchronous weather satellite are shown in Figure 2. Figure 3 gives an observation diagram for the postulated synchronous weather satellite system.

Additional development is to be carried out on techniques for measuring rainfall regions and ocean surface conditions by microwaves.

(1) Weather Observation Subsystems.

(a) Window infrared radiometer measurement of land surface, ocean surface, cloud top temperature as well as the observation of cloud distribution during the day and at night).

(b) Visible spectrum cameras (observation of cloud distribution during the day).

(2) Weather Data Collection and Distribution Subsystem.

(a) Collects weather data from ships and from automatic observation stations on the land and at sea and relays these data to the weather centers.

(b) Transmits forecasts, warnings, analytical data and weather maps etc., analyzed at the weather center to vessels and other users.

It is mandatory that the frequencies and codes used in these subsystems, etc., be universally standardized.

(3) The weight of the satellite will be approximately 300 kg. /12

(4) A CDA station (command and data acquisition) data processing center which will control the weather satellite and acquire data, will be needed.

(5) Satellites and [sic] subsystems to transmit and receive data (for example facilities for use in ships, buoys, etc.) will be needed.

(6) The targeted launch date is the end of 1975.

These elements can make observations about once every 20 minutes. Observations under (1) - (a) will have an accuracy of about 4 to 5 nautical miles, while those under (1) - (b) will have an accuracy of about 2 nautical miles.

III. Anticipated Results, Cost Comparison and Future Developments.

1. Anticipated Results.

Weather satellites provide the kinds of weather data given in the beginning of this pamphlet. Not only do these data include the requisite elements for weather analysis, their content is incomparably richer in terms of regional coverage, frequency of observation and types than those produced by the methods of the past. Thus, the utilization of satellite data naturally will be reflected in the daily weather analyses, as a result of which the accuracy of forecasts and warnings will be improved.

Two or three examples are given below.

(1) Principally the Improvement of Warning Accuracy and Weather Surveillance.

(i) The State of Typhoon Surveillance and Problems in Marine Forecasting.

Synchronous satellites provide information on storms such as typhoons, lows, etc., in the form of pictures at regular 20 minute intervals, making forecasts and warnings covering them accurately. In the past, the observation of clouds has been from the ground. In such methods, the limit of observation is on the order of 80 km, even with high clouds, but during poor weather and when the clouds are low, the limit is generally an area 1.0 to 20 /13 km square. It is not possible to cover extensive regions, even though observations of this type are interconnected. This is tantamount to having absolutely

no knowledge of ocean regions where there are no observation nets. Recently, it has become possible to acquire the cloud distribution in the vicinity of Japan from the American polar orbit satellites with automatic picture transmission equipment (APT). The frequency is one to two times daily.

Typhoons originate over the oceans in the tropics where there are virtually no islands. At the present time, typhoons are first discovered if their origin happens to be caught by cloud photographs from the United States weather satellites, if they are caught by one or another observation station in the South Sea Islands, after they have become quite large, or if they are observed by aircraft that regularly fly over fixed courses. Subsequent to initial discovery, the position and the force of typhoons is determined from the data collected by observation stations located around the typhoon, or from extraordinary typhoon observations made by United States military aircraft. Approximately one hour elapses between the time weather observations are made at the observations stations and the reports are received by the center. Approximately three hours elapse from the time these data are assembled and the pattern of the typhoon is determined. It is approximately 3.5 hours after the observations have been made that this information is generally disseminated.

Normally, observations of a typhoon are made four times daily during the initial period of its generation. Subsequent changes are confirmed by eight observations daily, that is to say once every three hours. Even when the results of aircraft observation are added to the data from the ocean areas, where there are few observation nets, there are times when there is a 30 to 40 nautical mile error in the determination of the position of the center. The pattern of typhoon movement is determined by differences in before and after observations. Thus, under favorable conditions, it takes three hours and under unfavorable conditions six hours, to confirm a sudden shift in the direction of a typhoon or its rapid development and the general dissemination of reports is even more delayed.

It may be said that the most important factors in the wrecking of a large number of fishing vessels and the loss of 208 men in the Mariannas region in 1965 were the delay in confirming the rapid development of the typhoon and the /14
changes in its course and delay in reporting this information. It is extremely

difficult to alleviate this situation in an ocean region where it is hard to strengthen the observation network.

(ii) Improving Marine Forecasts with Satellites.

As stated earlier, it is possible to regularly determine detailed cloud distribution every 20 minutes with an accuracy of about two nautical miles during the day and of about four to five nautical miles at night with synchronous satellites. Thus, not only is it possible to detect the origin of typhoons more accurately with such satellites, their development, strength and movement can be determined with incomparably greater accuracy than by the present methods. It is also possible to transmit this information through the satellite. As a result, typhoon analysis, forecast and warning will be accurate and losses can be dramatically reduced if appropriate reports receiving and transmitting measures are taken.

Similarly, such atmospheric disturbances as lows, (for example the Taiwan Bozu*, which occasionally causes great losses to fishing vessels), fronts, etc., which affect Japan, can be kept under constant surveillance and forecasts and warnings for such disturbances will probably be greatly improved.

(iii) Problems with Radar and its Joint Use with Satellites.

The great capabilities of radar are demonstrated when typhoons come within 300 km of the Japanese home islands. However, since the radar waves are reflected by rain as it falls from the clouds, radar can only observe rain distribution. In addition, these waves are also attenuated by the raindrops. For these reasons, radar cannot completely observe the leading edges of thick rain clouds, and, at times, the actual nature of the phenomena appears distorted. In order to observe typhoons by radar with the least possible error, it is desirable that the domestic radar nets be completely mobilized, both sides of the typhoon be observed and that the estimates be made on the basis of the combined observations. In this sense, the provision of a radar information transmittal network is the first step forward, however, the greater problem is the rapid transmission of radar images from, for example, Tanegashima and Moroto Misaki

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*Tr. Note: Lit: alopecia, a colloquial name for a type of sudden storm.

to the Weather Agency Analysis Center and the regional forecasting centers which assist it, which have the greatest responsibility for determining the position of typhoon centers and of forecasting their movement. /15

In order to accomplish this, it is necessary to tie in these centers with a minimum of two private telephone lines and picture receiving devices each and to connect them to the government offices. About 30 minutes is required to make the observations at a radar station, sketch them and transmit the observations by FAX. Even if it is possible to disseminate valid estimates based on these reports, an additional 30 minutes, or so, is required. Normally, there are slight disparities between the position of the eye of a typhoon as observed by radar and the location of the pressure center of the typhoon as derived from weather maps. For this reason, forecasting officers are hesitant to define and publish the position of the center in the hourly weather maps, which are completed about one hour after the observations have been made.

Even if it were possible to improve this situation by better working procedures, it would still appear to be difficult to make a determination within 30 minutes.

When typhoons begin to break up, they either have no eye, or the eye becomes completely impossible to observe. In addition, forecasting officers are often troubled by the abnormal courses taken by degraded typhoons which attack Japan around the beginning of the rainy season causing heavy rainfall. In the case of such typhoons, observation of the rainfall areas by radar alone is insufficient for a full grasp of the actual state of the typhoon, including the position of the center, development and degradation, making forecasting difficult. Even though there are no changes in rainfall distribution, there are many instances in which it is possible to observe precursory phenomena in the cloud distribution. In such instances, the addition of observation data on cloud distribution from synchronous satellites would be the same as adding a million allies in forecasting operations. Forecast accuracy can be increased by observing typhoon movement in cloud distribution photographs taken by synchronous satellites. Concurrently, the observation data on rainfall from radar and robot rain gauges can be added to the satellite reports and studies made by correlating the precipitation phenomena of typhoons and of other types of disturbances thereby

making it possible to further increase the accuracy of forecasts covering rainfall caused by typhoons. /16

(iv) General Flash Reporting of Satellite Information.

It goes without saying that the effectiveness of typhoon reports, when typhoons approach the home islands, derives from the early dissemination of more accurate forecasts. However, this effectiveness is also greatly increased by rapid dissemination of positive information on actual conditions. There are considerable difficulties attendant on the constant supply of radar images to all areas throughout the country. It would be a simple matter, however, to supply cloud distribution photographs obtained from a synchronous weather satellite to all of the population of the country as needed through the cooperation of NHK and other suitable information organs.

(v) In passing, it has been estimated that the losses from natural disasters in Japan average several hundred billion yen annually and that weather disasters, in which the deaths exceed 1,000, occur once every 2.5 years. It may be anticipated that improving the accuracy of forecasts and warnings would contribute greatly to reducing losses, particularly the losses of life on land and at sea.

(2) Principally, the Improvement of Forecast Accuracy by Numeric Forecasting.

(i) The Present State of Numeric Forecasting and Problems that Stem from the Observation Network.

The improvement of weather forecasting is principally accomplished by such scientific methods as numeric forecasts. At the present time, numeric forecasting is accomplished in the following way. Grid points are first taken at 300 km intervals on a weather map and the weather data for these points are calculated from a number of observation points that surround them. Next, an estimate is made by calculating the values for a period 24 or 48 hours later for each of these grid points using a movement formula which approximates the actual movement of the atmosphere. These results are then used to draw up a weather forecast map projected one or two days ahead that covers the large-scale flow of the atmosphere, instability conditions in the atmosphere and the

flow of water vapor. (Forecast accuracy for flow patterns 24 hours in advance is on the order of 80% at the present time). However, this system has not yet /17
reached the point of being actually satisfactory. One of the reasons why improvement cannot be achieved is that there are few actual measurement values available over extensive ocean areas. This reduces the accuracy of the hypothetical values for grid points in oceanic areas. In attempting to collate the calculated, predicted values with the actual state of the atmosphere, the latter conditions are not actually known, making it difficult to increase accuracy further.

(ii) The Contribution of Satellites to the Improvement of Numeric Forecasting.

As orbiting weather satellites can measure the vertical distribution of the atmosphere from the stratosphere to the altitude of the cloud layers, they are combined with a global stratospheric observation network established under the WWW Plan. As a result of the development of a global weather satellite system, data covering the entire globe can be obtained and the previously described grid point values all will be measured values. Concurrently with progress towards the development of a more accurate movement formula, it will be possible to make usable forecasts of large-scale atmospheric flow patterns two to three weeks or more in advance. The accuracy of the 10 day forecasts, which forecast daily weather conditions over extensive areas for 10 day periods in advance will be improved. (The fact that the accuracy of forecasts of flow patterns one month in advance is 60%, means that the accuracy of forecasts for flow one day in advance will be 98%).

(iii) The Improvement of Local Forecasts.

By further, parallel progress in studies of the mutual correlation between these flow patterns and weather conditions in each of the local areas (at the present time, it is possible to establish an approximately 80% correlation), it will be possible to dramatically improve the accuracy of the local forecasts that are desired by the population and to extend the forecast period.

As a result of the above, it is not a dream that the accuracy of local time-series forecasts (at the present time it is not possible to forecast the

hourly changes in various weather elements, for example, rain, air temperature, humidity, etc. Even when possible, the accuracy is generally on the order of 60%), will be about 80%. These forecasts will be prepared by collating the constant observations of synchronous weather satellites and observations of rain areas by radar with the measured values reported by robot rain gauges and other land-based observations and effecting suitable corrections. By appropriately disseminating these to the people,it can be anticipated that forecasting service will be vastly improved. /18

(3) The Effects on Data Collection and Distribution.

In America, more than some 10,000 items of weather data, including precipitation, water levels and flow, automatic hygrometer weather data, automatic earthquake observation data, etc., are collected. If automation of the necessary observations can be achieved domestically in Japan, in addition to robot precipitation observations and coastal disaster observations, it would facilitate the rapid collection of these data. Accordingly, the ready acceleration of their use would probably serve to increase the value of reports.

Additionally, the automatic collection of weather data from vessels, from which there has been a sharp reduction in data reporting because of the curtailment of communications personnel, particularly at night, would be improved, and the transmission of useful reports to vessels would also be facilitated.

(4) Economic Evaluation of the Results.

It is not easy to estimate the value of five to seven day forecasts, however, the economic profit to the production industries that are affected by changes in the weather (agriculture, maritime transportation, aviation, construction, public works, hydroelectric power, etc.) would probably be so great as to defy comprehension. Two or three test computations may be given.

(i) The Benefits to American Construction Industries.

Let us quote from test computations (1962) concerning the United States construction industries made by Dr. White of the United States Environmental Sciences Services Administration for a study entitled "The Economic Benefits of Short-Term Forecasts," which was accomplished under the aegis of the WMO. /19

Annual investments by the United States construction industries totals 31.68 trillion yen (88 billion dollars). Of this, that portion that is affected by the weather amounts to 14.29 trillion yen (39.7 billion dollars). Losses attributable to weather are estimated to be a minimum of 1.8 trillion yen (three billion dollars). These amounts are with the currently published forecasts. However, were the method of using forecasts improved, it would be possible to save 180 billion yen (500 million dollars) of this amount. Were forecast accuracy increased 20%, it is believed that these savings would rise to 540 billion yen[2] (1.5 billion dollars). Now, since the annual investments of the Japanese construction industries is 10.2 trillion yen (1968 estimate), the savings in losses suffered by the construction industries alone would be 87 billion yen, with an increase in forecast accuracy of 10%, calculating with the same rates as those used for America.

(ii) Economic Benefits of Five-Day Forecasts.

According to a study commissioned by the American government, the annual loss savings in agriculture, transportation and hydroelectric power resulting from five-day forecasts would rise to 2.16 trillion yen (six billion dollars). According to a study backed by the WMO covering the world economy as a whole, this amount would be 6.12 trillion yen (17 billion dollars). In a more accurate study of the British economy, it is stated that this figure would attain a minimum annual total of 86.4 billion yen (100 million pounds).

If, as in Paragraph (i), forecast accuracy were increased by 20%, the loss savings would be, respectively, 720 billion yen, 2.52 trillion yen and 22.8 billion yen. /20

(iii) The Benefits of Long-Range Forecasts and Weather Satellite Construction Costs.

Let us cite an article published in the United States. Space Magazine (October 1967).

Weather satellites offer services that fully repay the costs of development, construction and launching. The National Academy has postulated that long range forecasts of high accuracy can reduce weather losses by a total of 126 billion

2. As stated earlier, it is given that the accuracy of the present local forecasts is 60%. This sum is applicable when that accuracy is raised to 80%.

yen (3.5 billion dollars) in a five-year period. Conversely, it should be noted that four TIROS weather satellites were ordered from RCA at a cost of 10.8 billion yen (30 million dollars).

2. Cost Comparison of Methods Dependent on Conventional Techniques and Facilities and those Dependent on Weather Satellites.

Weather observations demonstrate their true value when the conventional ground and stratospheric observations, radar observations, etc., are complemented by weather satellite systems. Accordingly, let us make two or three trial calcuations, bearing in mind that the respective functions of these systems are different and the defense limits that each provides is peculiar to that system alone. (The costs of weather satellites are difficult to estimate, however the cost of one has been estimated at about four billion, excluding development costs.) Adding launching costs of about three billion yen and given a lifetime of about 3 to 5 years, annual operating costs are on the order of 1.4 to 2.3 billion yen.

For example:

(1) Stratospheric observations over the ocean are accomplished by placing a stationary weather observation ship at each of a number of points on the ocean. At the present time, only four such points have been developed in the Pacific Ocean and nine in the Atlantic. The reason that this is so is that high expenditures and large numbers of personnel are needed to maintain stationary observation ships. If it is given that observation ships would be deployed at 1,000 km intervals to form the basic observation net recommended by WMO in the ocean region for which Japan has weather service responsibilities, (0° to 60°N, 120° to 180°E) some 40 ships would be required. The construction /21
cost for one observation ship for one point is about one billion yen giving a construction cost requirement of about 40 billion yen, even if relief ships are not considered. Annual operating costs for two stratospheric observations daily per vessel are calculated at 300 million yen, to give a total annual requirement of about 12 billion yen. Even at this rate, the number of stratospheric observations are fewer than those of satellites and cloud distribution cannot be observed. As a practical solution, it will probably be impossible to develop observation ships in this way.

(2) To conduct typhoon surveillance in the region south of Japan, (120° to 160°E, 10° to 35°N, scheduled flights may be considered for typhoon detection and special flights for typhoon surveillance. Given a total of eight jet aircraft, the construction cost for the first year would be 11 billion yen, while about 4.5 billion yen would be required for annual maintenance (including personnel costs). About 400 men would be needed. To talk about the surveillance limits with this method, a scheduled route is, for example, the 2,000 to 3,000 km triangle Tokyo-Guam-Okinotori Shima-Tokyo, which does not by any means thoroughly cover the south seas. Further, the area over which the clouds can be observed is not as extensive as that provided by a satellite. Even the special typhoon flights cannot be flown more than four times daily.

3. Future Development of Weather Satellites.

During the ten-odd years since an artificial satellite was first launched in 1957, space technology has developed to a startling degree. Weather satellite techniques will also develop more and more in the future and the future of this technology defies imagination.

It is believed, however, that the following functions will be realized in the near future. It may be anticipated that new weight will be added to the reduction and prevention of water damage, marine disasters and weather losses.

(1) Surveillance of rain areas and precipitation measurements on a global basis.

(2) Surveillance of ocean surface conditions (waves, sea ice, ocean currents, etc.).

(3) Measurement of such atmospheric elements as ozone, carbon dioxide gas, etc.: surveillance of atmospheric pollution conditions. /22

APPENDIX

THE NEED FOR INDEPENDENT DEVELOPMENT IN JAPAN

1. Why do Australia and Other Foreign Countries Not Bear a Portion of the Costs of Satellites?

(i) Synchronous satellites have a higher degree of domestic utility than orbiting satellites.

Unless the observed cloud distribution photographs pass through a CDA station, they cannot all be acquired. Specifically, the observation data made every 20 minutes can only be acquired by a CDA station that is tied to that satellite.

The data acquired by the CDA station are suitably expanded and transmitted on a narrow band (frequency band width). However, considering electric power consumption in the satellite and other communications missions, not all of the data acquired is transmitted. Were this to be attempted, the size of the satellite would have to be increased and this would mean additional costs. (Requirements to underwrite these costs might be laid on the foreign countries that make such requests). Transmissions would increase and would probably total some three hours each time. Domestic requirements take first place in the acquisition of data over the land and the ocean and, at least for the first satellite, and except for vessels, consideration is not being given to the acquisition of data for foreign countries.

(ii) On the basis of the above, a division of the utilization of synchronous satellites into domestic and foreign service might be calculated as follows.

Acquisition of cloud observation data:	Domestic:	9 times
	Foreign:	1 time
Acquisition of surface observation data:	Domestic:	90%
	Foreign:	10%

From the above, the domestic : foreign utility rates would be generally on the order of 90% : 10%.

(iii) Since the first satellite is experimental, it is not possible to appeal to foreign countries to bear a portion of the cost.

(iv) The load for satellite observations as viewed from Japan's responsibility for weather service and benefits may be calculated as follows. /24

(a) For the most part, orbiting satellites can be used in common globally and there is little independent value to the country which owns it. This ratio probably is on the order of domestic 10 and foreign 90. The value to other foreign countries may be accepted at being proportional to the size of the sea and air region for which such countries are responsible. Accordingly, the value to our country if the proportional size of the area of 100° to 180°E, 0° to 60°N to the area of the world.

$$\frac{80}{360} \times \frac{1}{2} = \frac{1}{9}$$

(b) The benefit to our country of a synchronous satellite in the area south of Japan is 9/10.

(c) Accordingly, given that the value of a weather satellite is four billion yen, launching costs are three billion yen for a synchronous satellite and are two billion yen for an orbiting satellite, the benefit to our country of a global weather satellite system will be as follows.

	Cost			Benefit to Japan						
	(Satellite)		(Launching)	Number		Area		Content		Cost (100 million)
Orbiting Satellite	(40	+	20)	x 5	x	1/9	x	9/10	=	30
Synchronous Satellite (Japan)	(40	+	30)	x 1	x	1	x	9/10	=	63
(Other countries)	(40	+	30)	x 3	x	1/9	x	1/10	=	2

Total - 9.5 billion yen

Thus, by cooperating with the world in launching one synchronous satellite at a cost of seven billion yen, it may be estimated that Japan will have

accomplished work equivalent to an expenditure of 9.5 billion yen.

2. Should All Launchings be Ordered from America?

(i) As stated above, synchronous satellites are, for the most part, special satellites of a domestic nature. The weather service requirements of /25
each country vary somewhat with the differences in weather conditions in that country. For example, Japan is a small country which contains a large population. Not only is the population density high, based on world standards, but, owing to the peculiarities of the middle latitude ocean climate, the damage from concentrated heavy rain and snowfall is much greater than it is in other countries, creating a great problem for Japan. In America, the problem is tornados, which do not occur too often in Japan.

(ii) As stated earlier, the acquisition of domestic ground observation data is principally for domestic use and this must be considered in the relationship between satellites and ground facilities.

(iii) On the basis of the above, it only follows that Japan should be considered as the user in designing a synchronous satellite system into which a Japanese flavor can be built and the determination of requirements should be by Japan.

(iv) It is necessary that the user determine the requirements and let the contracts on the basis of these requirements, as well as perform follow-up inspections. In large systems such as satellites, it is mandatory that close coordination be maintained with the prospective contracting companies beginning with the initial stages of requirements determination. Were reliance to be placed on an American contractor, there would be major geographical and linguistic disadvantages. It appears that there would be an increase in cost of about 200 million yen over an order with a Japanese contractor annually, or a total of about one billion yen for the five years that would pass until construction had been completed. From the viewpoint of foreign language problems, there would probably be attendant difficulties in securing full response to Japan's wishes.

(v) For the first satellite, it might well be possible to reduce a certain portion of development costs were a satellite of exactly the same type as that now being considered in America to be ordered from the United States. It would be a different matter were Japan to completely halt space development. Were space development to continue here, however, of the approximately five billion yen in development costs to be expended for weather satellite No. 1, it may be anticipated that one to two billion yen will be paid for orders placed in America. Of the remaining three to four billion yen, about 70%, that is to say, 2.1 to 2.8 billion yen would be for parts common to other satellites. For this reason, that expenditure would serve to reduce development costs in the future for other types of satellites, for example, resources sat- /26
ellites, for example, resources satellites, navigation satellites and communications satellites. The remaining 900 million to 2.2 billion yen would be used in the development of the weather satellite itself. As this amount is almost equal to the previously stated increased cost of ordering a satellite from America, it represents an economy for the second and subsequent satellites. Considering other technological fallout, it would appear to be to Japan's advantage to carry on development beginning with the first satellite.

3. On Bearing the Burden of Future Costs.

When the future global weather satellite system is established and goes into operation, it is probable that there will be further debate in WMO, etc., on maintenance costs for the appropriate apportionment of the burden, just as is done with the present, fixed observation costs, based on the benefits to each country and the capability of each country to bear the economic burden. As stated in the first paragraph, however, it appears highly improbable that the burden borne by Japan will vary to any great extent.

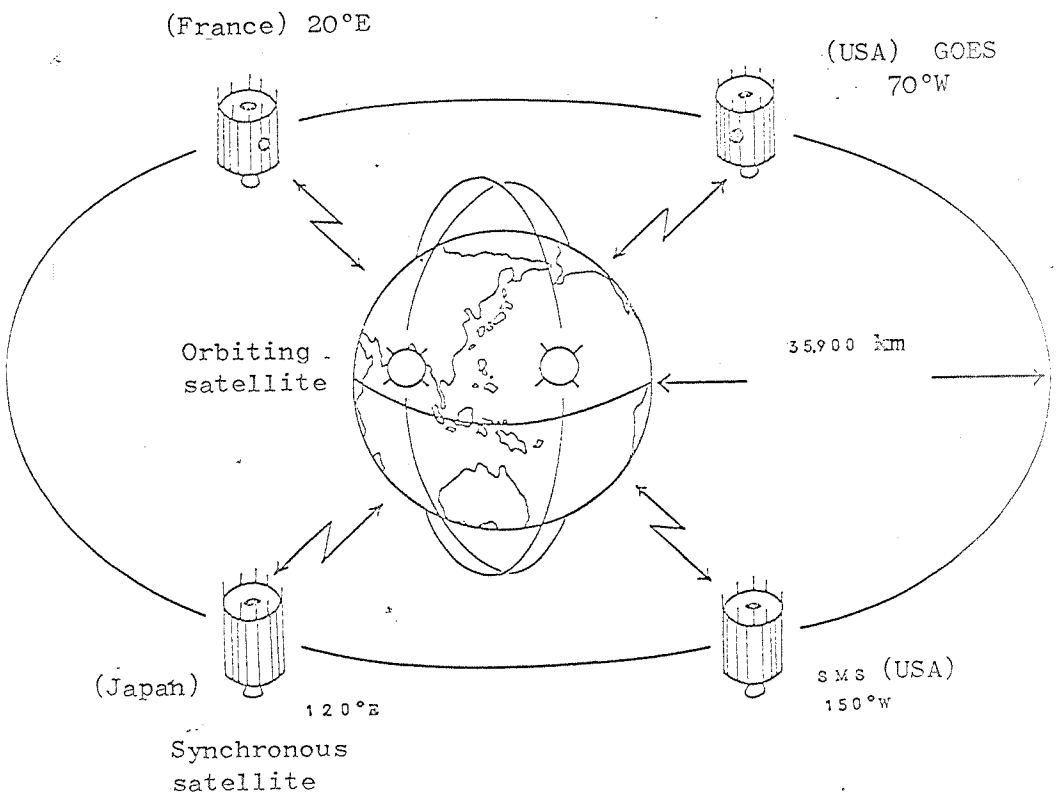

Figure 1. Global weather satellite deployment under GARP.

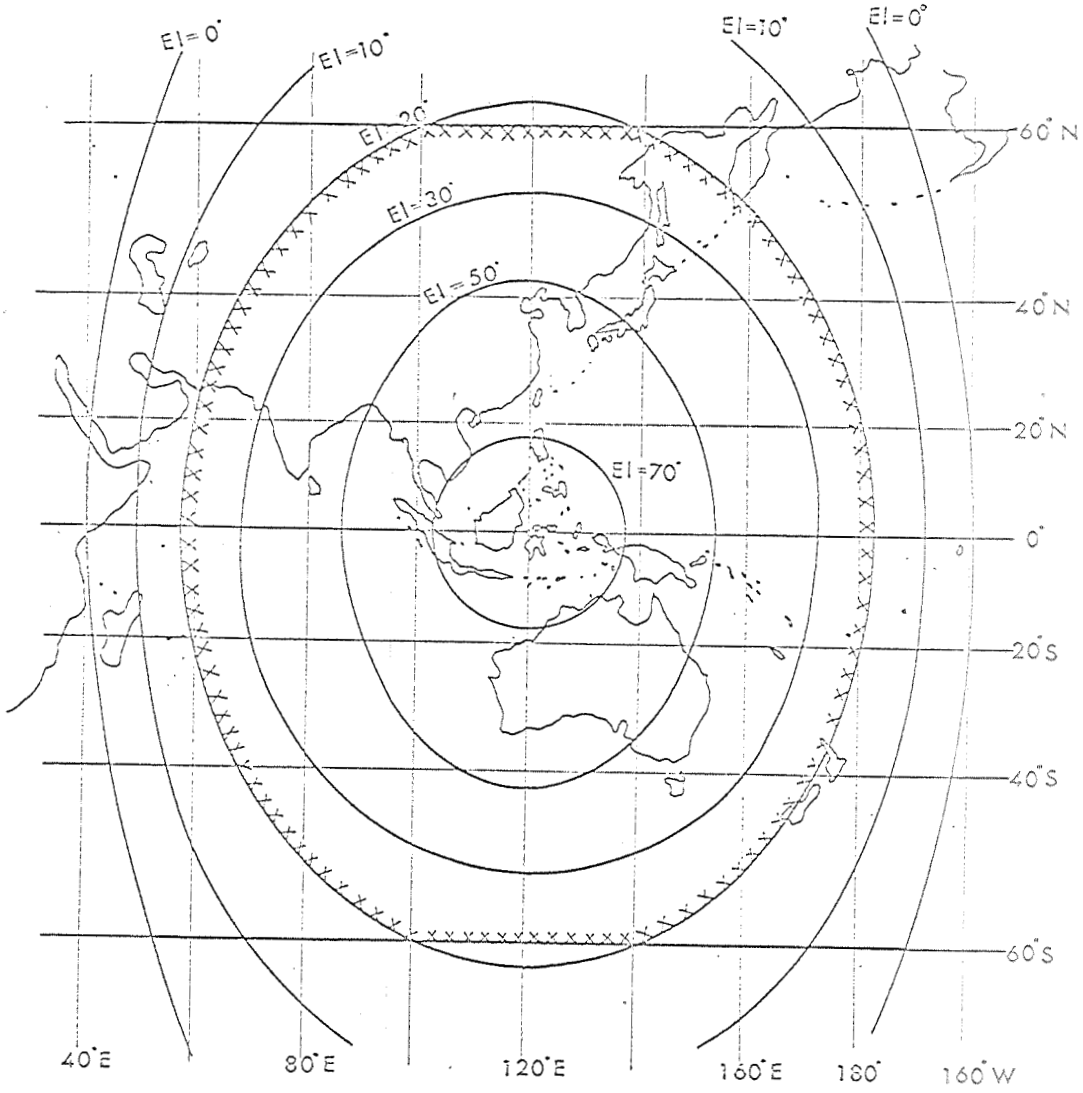

Figure 2. Surveillance range of a synchronous satellite.

The hatched line shows the region in which cloud distribution can be observed. El = 50° represents those points at which the altitude of the satellite is 50°.

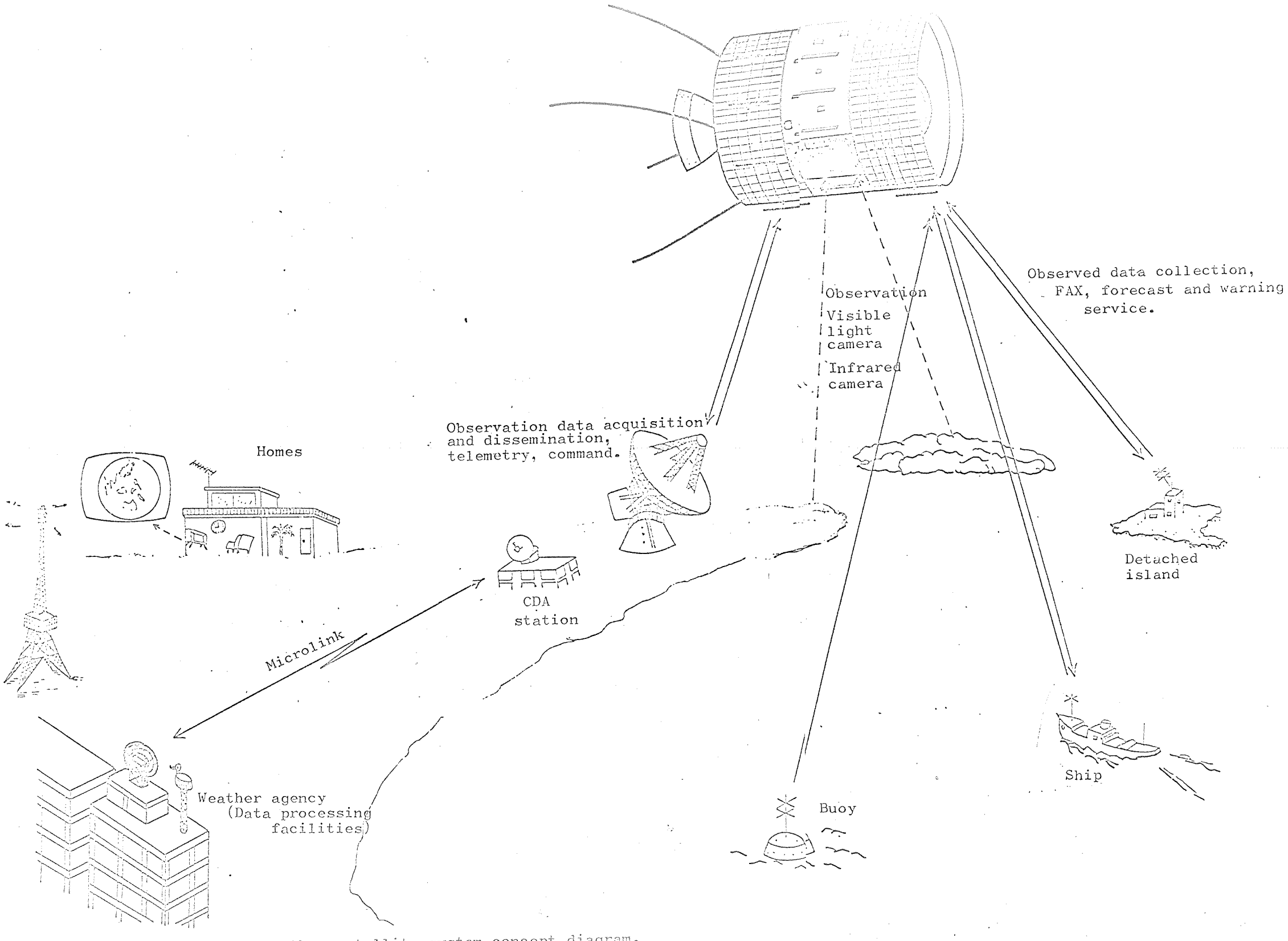

Figure 3. Synchronous weather satellite system concept diagram.